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SUMMARY: To investigate the effects of air pollution on the respiratory health of children, a subject of some controversy, a comparative study was undertaken of 2,385 school children who lived in central urban, peripheral urban, and suburban areas. Daily monitoring of sulphur dioxide and total suspended particle concentrations in all areas showed that pollutant concentrations in central and peripheral urban areas were above commonly accepted safety levels for respiratory health, while concentrations in the suburban area were within acceptable limits. A questionnaire administered to each mother assessed environmental exposure to pollutants in the household, the occurrence of respiratory symptoms as well as lung diseases as diagnosed by a physician, and general information. Children were interviewed about smoking habits and any acute respiratory symptoms. Children also performed standard lung function tests. Results showed that children from both urban areas had lessened pulmonary function and a higher prevalence of bronchial secretion with common colds than did those from the suburban area. These differences persisted after corrections for exposure to indoor pollutants, active or passive smoking, socioeconomic status, and sex. Parental cigarette smoking was related to a fall in forced expiratory volume in 1 second and an increased incidence of acute respiratory illnesses and chronic cough in children. Although boys had higher lung volumes and lower air flow, regression analysis showed no significant influence of the interactions "sex-geographic area" and "sex-smoking" on lung function. It was concluded that air pollution had a significant effect on the respiratory health of children.

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# The Effects of Air Pollution on the Respiratory Health of Children:

## A Cross-sectional Study

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**Summary.** To investigate the effects of air pollution on the respiratory health of children, a subject of some controversy, a comparative study was undertaken of 2,385 school children who lived in central urban, peripheral urban, and suburban areas. Daily monitoring of sulphur dioxide and total suspended particle concentrations in all areas showed that pollutant concentrations in central and peripheral urban areas were above commonly accepted safety levels for respiratory health, while concentrations in the suburban area were within acceptable limits. A questionnaire administered to each mother assessed environmental exposure to pollutants in the household, the occurrence of respiratory symptoms as well as lung diseases as diagnosed by a physician, and general information. Children were interviewed about smoking habits and any acute respiratory symptoms. Children also performed standard lung function tests. Results showed that children from both urban areas had lessened pulmonary function and a higher prevalence of bronchial secretion with common colds than did those from the suburban area. These differences persisted after corrections for exposure to indoor pollutants, active or passive smoking, socieconomic status, and sex. Parental cigarette smoking was related to a fall in forced expiratory volume in 1 second and an increased incidence of acute respiratory illnesses and chronic cough in children. Although boys had higher lung volumes and lower air flow, regression analysis showed no significant influence of the interactions "sex-geographic area" and "sex-smoking" on lung function. It was concluded that air pollution has a significant effect on the respiratory health of children. (*Key words:* active and passive smoking; respiratory health of children; sulphur dioxide; total suspended particle conc.; urban vs suburban air pollution.) *Pediatr Pulmonol 1985; 1:262–266.*

Although many authors have reported that air pollution has a negative effect on the respiratory health of children,[1–6] this finding has not been confirmed by others.[7–9] According to Ericsson and Camner[10] these contrasting results could be due either to the different degree of exposure of the tested populations or to the inadequate assessment of exposure when data collected from one or two monitoring stations are considered to be representative for the whole area.

The purpose of the present study was to compare the respiratory health of children from two urban areas with that of a control group from a suburban, semirural area. All subjects lived within 500 meters from a monitoring station.

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## Methods

The study was undertaken during the winter of 1980–1981 in two urban areas of Turin, one central (UC) and one peripheral (UP), and in a suburban area (SU) that served as a control.

Seven stations scattered throughout each of the three areas monitored daily sulphur dioxide ($SO_2$) and total suspended particle (TSP) concentrations. $SO_2$ was measured using a coulometric analyzer (PW 9,700 Philips, Philips Electronic Instruments Inc., Mahwah, N.J.) and TSP by a gravimetric method (Gelman low rate sequential sampler, Gelman Sciences, Inc., Ann Arbor, Mich.).

To ensure as far as was possible that the population had been uniformly exposed to air pollutants, we recruited, in each of our three geographic locations, children living in the same area who were attending the sixth grade at a junior high school located within 500 meters from a monitoring station.

Respiratory health was assessed by means of lung function measurements and a question-



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naire. The questionnaire, administered to mothers, supplied information about general data, environmental exposures to pollutants in the household, respiratory symptoms, lung diseases diagnosed by a physician, and parental history; the latter included questions about education, occupation, smoking habits, and respiratory health. Each child was interviewed confidentially about his or her smoking habits and any acute respiratory symptoms.

Flow-volume curves were obtained by means of a Hewlett-Packard 40801 M computerized pneumotachograph (Hewlett-Packard Company, Waltham, Mass.). The best forced vital capacity (FVC), forced expiratory volume in 1 second ($FEV_1$), forced expiratory flow between 25 and 75% of FVC ($FEF_{25-75}$), and maximal expiratory flow at 50% of FVC ($\dot{V}max_{50\%}$) were selected according to Taussig et al.[11] Lung function tests were not performed until ten days following recovery in subjects with acute respiratory illness.

General linear model analysis (GLM) was done taking lung function values as dependent variables.[12] The set of independent variables included: geographic area; sex (male = 1, female = 0); age; height; body weight; active and passive smoking (yes = 1, no = 0, and daily number of cigarettes); socioeconomic status defined as father's total years of education; central heating (yes = 1, no = 0); type of stove (gas = 1, electric = 0); and exhaust hood (unused = 1, used = 0). Geographic areas were compared using Sheffe's method.[13]

To evaluate the effect of air pollution on respiratory symptoms and diseases a logistic regression analysis[14] was performed using geographic area, sex, active and passive smoking, socioeconomic status, central heating, stove type, and exhaust hood use as independent variables. The interactive effect of independent variables as they related to dependent variables (lung function; respiratory symptoms and illnesses) were evaluated, and the usual criteria for significance were used.

## Results

The mean concentrations of pollutants for the winter months (October to April) as well as for the year in the three areas are shown in Figure 1.

Out of 2,439 eligible children, 2,385 (1,266 boys and 1,119 girls) entered the study. The remaining 54 subjects were not included because of parental objections (14 cases) and other reasons.

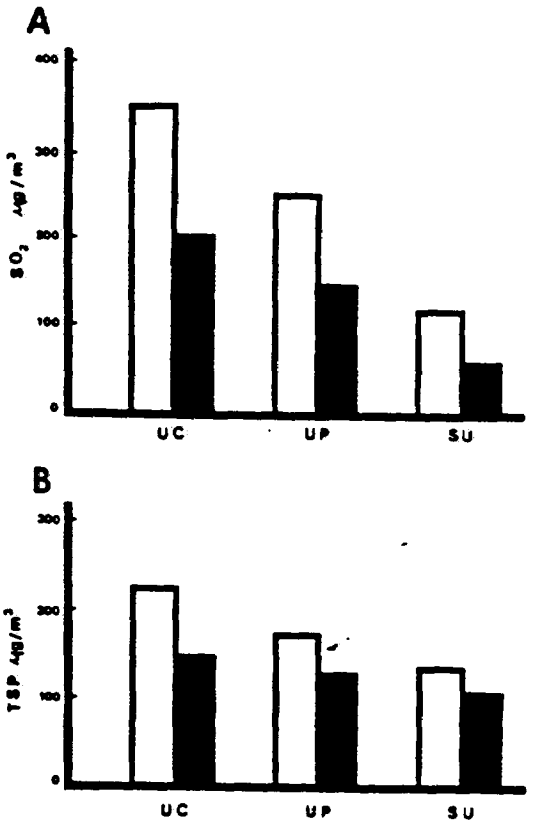


figure 1—Concentrations of (*top*) Sulphur dioxide ($SO_2$)and (*bottom*) total suspended particles (TSP) in central (UC), peripheral (UP) and suburban (SU) areas during the winter (October to April) of 1980–1981 (white bars) and for the whole year (dotted bars).

General data (Table 1) indicated that the number of boys was greater, although not significantly so, in UP, while the socioeconomic status was significantly higher in SU. As the prevalence of current smokers was very low (1.3%), children who had smoked even one cigarette during their lifetime were considered to be smokers; a significantly higher prevalence of smoking was found in UC ($P < 0.01$).

The adjusted prevalence rates of respiratory symptoms and illness computed from logistic multiple regression (table 2) showed that the rate of bronchial secretions with common colds was significantly higher in urban areas, while that of asthma was significantly lower. Although some symptoms and diseases were less common among girls, we did not observe any interaction

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**table 1**—Characteristics of the Study Population by Geographic Area and Sex in Absolute Numbers, Nearest Percentage or Mean (SD)

| | Boys | | | Girls | | |
|---|---|---|---|---|---|---|
| | UC | UP | SU | UC | UP | SU |
| No. of subjects | 359 | 813 | 94 | 360 | 668 | 91 |
| Age (years) | 11.2 (0.4) | 11.3 (0.4) | 11.1 (0.4) | 11.1 (0.4) | 11.3 (0.4) | 11.2 (0.4) |
| Height (cm) | 148 (7.0) | 149 (7.0) | 149 (7.0) | 146 (7.0) | 147 (7.0) | 147 (7.0) |
| FTE (years) | 6.1 (3.0) | 6.2 (3.5) | 6.8 (3.2) | 6.1 (2.8) | 6.3 (3.6) | 6.9 (3.2) |
| Smoking habit (%) | | | | | | |
| Father | 60 | 62 | 54 | 65 | 62 | 59 |
| Mother | 23 | 23 | 25 | 23 | 24 | 21 |
| Child* | 15 | 7 | 4 | 9 | 5 | 3 |
| Exhaust hood (%) | 28 | 21 | 43 | 30 | 20 | 46 |
| Gas stove (%) | 99 | 99 | 99 | 99 | 99 | 99 |
| Central heating (%) | 30 | 29 | 32 | 31 | 29 | 31 |

Key:
UC = urban central.
UP = urban peripheral.
SU = suburban.
FTE = father's total years of education.
* The prevalence of smoking in UC vs other areas is significant ($P < 0.01$).

of the variable sex–geographic area and respiratory illness. The number of cigarettes smoked by both father and mother (UC) had a significant negative effect on the rate of cough with colds ($P < 0.01$) and acute respiratory illness ($P < 0.01$). There was a strong correlation between active smoking and a significant increase in the rate of chronic cough ($P < 0.01$), but this symptom had such a low prevalence that the finding must be regarded with caution.

We detected, in both sexes, a significant association between geographic area and lung function (Table 3), with a lower $FEV_1$ and forced airflow rates being observed in both urban areas. Notwithstanding the difference between sexes, the interaction sex–geographic area produced no further effect on lung function.

The $FEV_1$ was significantly decreased by passive smoking ($P < 0.01$); child $FEV_1$, $\dot{V}_{max}$, and $\dot{V}_{max}$ were affected negatively by active smoking ($P < 0.01$). Active smoking by mother or father, the use of a gas stove and exhaust hood, and all the other interactions had no statistically significant effect on lung function.

## Discussion

The significantly lower $FEV_1$ and airflow rates and the higher prevalence of bronchial secretion during acute respiratory infections found in children from the two urban areas suggest that a consistent level of air pollution has a negative effect on respiratory health. In both urban areas the annual average concentrations of $SO_2$ and particulates were well above 100 $\mu g/m^3$, a level that, according to the World Health Organization,[16] can cause adverse effects.

The results of this study are in agreement with those reported by Saric[2] and Chapman in a population exposed to similar levels of air pollutants. Although other authors have not found that exposure to air pollution has any significant effect on respiratory health, this discrepancy is probably due to in one instance to an insufficient sample size[9] and in another to the negligible pollution concentrations.[8] The results of a study that had both an adequate sample size and levels of pollution (Kerrebjin[7]) could have been affected by the selection of a geographic area as a control that had been cleaned only one year before the study.

In accord with the findings of Rasmussen et al. in adults,[17] we found higher expiratory flows in children living in houses with central heating. Indoor air pollution, expressed as the presence of gas stoves and unused exhaust hoods, had no significant effect on respiratory health, confirming the results of Melia.[18]

Both active and passive smoking had a negative effect on respiratory health. Passive smoking only had an adverse effect when both parents smoked; no association was found between children's respiratory health and maternal smoking. This finding is at variance with other reports[19-20] and can be explained by the low ex-

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posure of our population to maternal smoking because of the small numbers of mothers who smoked and the high numbers who worked outside the home (40%).

Although, as has been reported previously,[21–23] boys from the three areas had 1) a higher prevalence of wheezing, shortness of breath, and asthma; 2) lower airflow rates; and 3) higher lung volumes, no significant influence of the interaction sex–geographic area on lung function or respiratory illness was detected. In contrast with other studies[19,24,25] we did not observe that boys had a different sensitivity to passive or active smoking than did girls. In our population, sex did not modify the response to air pollution and smoking.

The greater number of asthmatics in the SU group was independent of socioeconomic status and might be due to a higher allergen concentration in this semirural area. This hypothesis needs to be confirmed by pollen monitoring and allergologic studies.

We conclude that air pollution, active smoking, and passive smoking when both parents smoke have a negative effect on the respiratory health of children.

table 2—Prevalence (%) of Respiratory Illness and Symptoms Adjusted for Socioeconomic Status and Active and Passive Smoking in the Three Geographic Areas

| | Geographic Areas | | | | |
|---|---|---|---|---|---|
| | UC | UP | SU | Effects | p |
| Cough with colds | | | | | |
| Boys | 48.1 | 48.0 | 48.2 | Area | NS |
| | | | | Sex | NS |
| Girls | 42.0 | 43.1 | 41.2 | Sex, Area | NS |
| Chronic cough | | | | | |
| Boys | 0.6 | 0.5 | 0.4 | Area | NS |
| | | | | Sex | NS |
| Girls | 0.7 | 0.6 | 0.5 | Sex, Area | NS |
| Bronchial secr. | | | | | |
| Boys | 23.8 | 22.2 | 15.1 | Area | <0.01 |
| | | | | Sex | NS |
| Girls | 21.8 | 21.1 | 15.0 | Sex, Area | NS |
| Chronic bronchial secr. | | | | | |
| Boys | 0.8 | 0.8 | 0.6 | Area | NS |
| | | | | Sex | NS |
| Girls | 0.9 | 0.8 | 0.6 | Sex, Area | NS |
| Wheezing | | | | | |
| Boys | 5.5 | 5.5 | 5.3 | Area | NS |
| | | | | Sex | <0.01 |
| Girls | 2.1 | 2.1 | 2.0 | Sex, Area | NS |
| Shortness of breath | | | | | |
| Boys | 3.0 | 3.1 | 3.9 | Area | NS |
| | | | | Sex | <0.01 |
| Girls | 1.5 | 1.8 | 1.6 | Sex, Area | NS |
| Asthma | | | | | |
| Boys | 1.6 | 1.8 | 4.3 | Area | <0.01 |
| | | | | Sex | <0.01 |
| Girls | 0.7 | 0.8 | 1.1 | Sex, Area | NS |
| ARI | | | | | |
| Boys | 20.1 | 20.5 | 21.0 | Area | NS |
| | | | | Sex | NS |
| Girls | 19.2 | 19.8 | 21.0 | Sex, Area | NS |
| RT(2) | | | | | |
| Boys | 16.0 | 15.5 | 16.1 | Area | NS |
| | | | | Sex | NS |
| Girls | 15.9 | 16.0 | 16.2 | Sex, Area | NS |

Key:
UC = urban central.
UP = urban peripheral.
SU = suburban.
ARI = acute respiratory illness in the last two years.
RT(2) = respiratory troubles in the first two years of life.

table 3—Means of Lung Function Measures Adjusted for Age, Height, Socioeconomic Status, Active and Passive Smoking, and Central Heating in the Three Geographic Areas

| | Geographic Areas | | | | |
|---|---|---|---|---|---|
| | UC | UP | SU | Effects | p |
| FVC (l) | | | | | |
| Boys | 2.77 a | 2.76 a | 2.81 a | Area | NS |
| | | | | Sex | <0.001 |
| Girls | 2.57 b | 2.59 b | 2.57 b | Sex, Area | NS |
| $FEV_1$ (l) | | | | | |
| Boys | 2.36 a | 2.36 a | 2.42 b | Area | <0.001 |
| | | | | Sex | <0.001 |
| Girls | 2.27 c | 2.31 c | 2.34 d | Sex, Area | NS |
| $FEF_{25-75\%}$ (l/s) | | | | | |
| Boys | 2.76 a | 2.82 a | 2.91 b | Area | <0.001 |
| | | | | Sex | <0.001 |
| Girls | 2.98 c | 3.04 c | 3.13 d | Sex, Area | NS |
| $\dot{V}_{max50}$ (l/s) | | | | | |
| Boys | 3.28 a | 3.30 a | 3.41 b | Area | <0.020 |
| | | | | Sex | <0.001 |
| Girls | 3.50 c | 3.52 c | 3.66 d | Sex, Area | NS |

Key:
UC = urban central.
UP = urban peripheral.
SU = suburban.
a, b, c, and d indicate differences among areas (identical letters mean no significant difference).

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